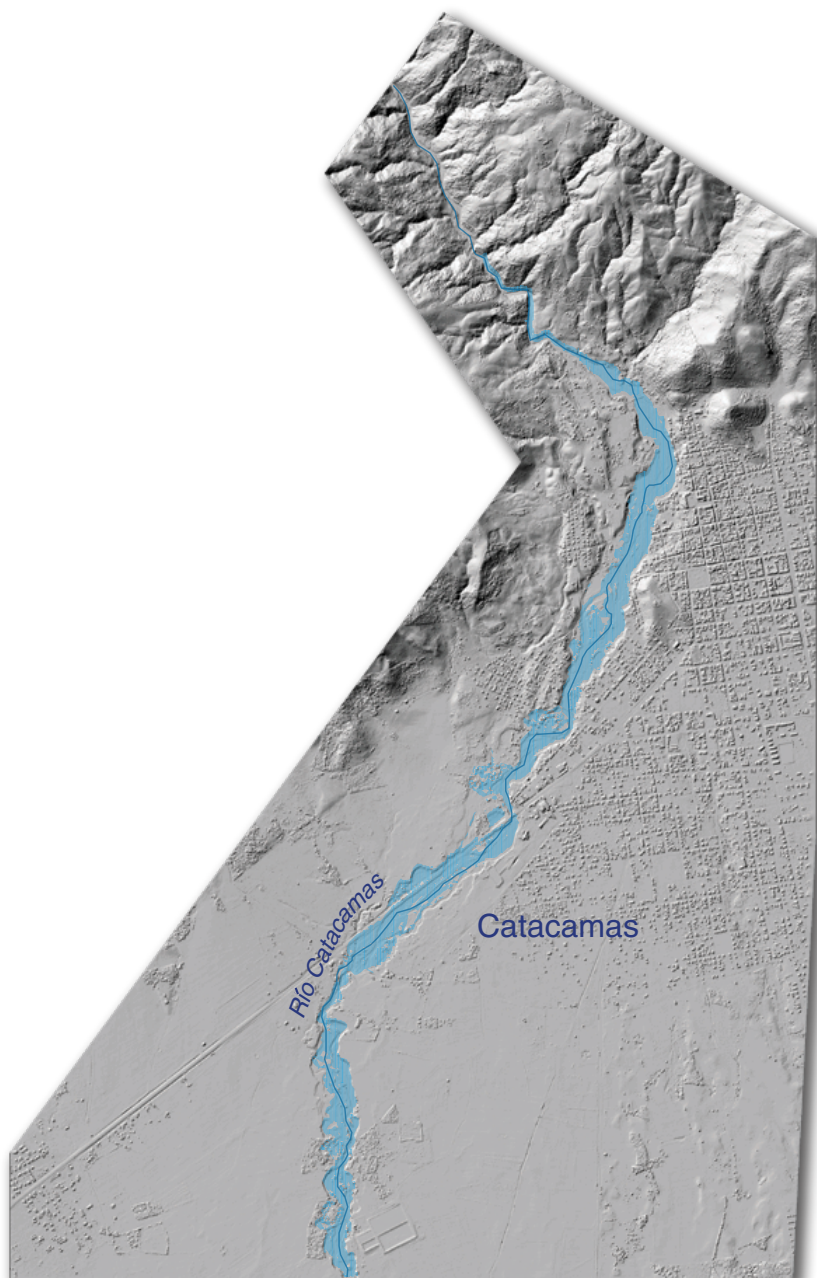




Prepared in cooperation with the U.S. Agency for International Development

Fifty-Year Flood-Inundation Maps for Catacamas, Honduras

U.S. Geological Survey Open-File Report 02-248



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By David L. Kresch, Mark C. Mastin, and Theresa D. Olsen

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CONVERSION FACTORS AND VERTICAL DATUM

CONVERSION FACTORS

Multiply	By	To obtain
cubic meter per second (m ³ /s)	35.31	cubic foot per second
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
millimeter (mm)	0.03937	inch
square kilometer (km ²)	0.3861	square mile

VERTICAL DATUM

Elevation: In this report "elevation" refers to the height, in meters, above the ellipsoid defined by the World Geodetic System of 1984 (WGS 84).

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ABSTRACT

After the devastating floods caused by Hurricane Mitch in 1998, maps of the areas and depths of the 50-year-flood inundation at 15 municipalities in Honduras were prepared as a tool for agencies involved in reconstruction and planning. This report, which is one in a series of 15, presents maps of areas in the municipality of Catacamas that would be inundated by a 50-year-flood of Río Catacamas. Geographic Information System (GIS) coverages of the flood inundation are available on a computer in the municipality of Catacamas as part of the Municipal GIS project and on the Internet at the Flood Hazard Mapping Web page (<http://mitchnts1.cr.usgs.gov/projects/floodhazard.html>). These coverages allow users to view the flood inundation in much more detail than is possible using the maps in this report.

Water-surface elevations for a 50-year-flood on Río Catacamas at Catacamas were estimated using HEC-RAS, a one-dimensional, steady-flow, step-backwater computer program. The channel and floodplain cross sections used in HEC-RAS were developed from an airborne light-detection-and-ranging (LIDAR) topographic survey of the area. The 50-year-flood discharge for Río Catacamas at Catacamas, 216 cubic meters per

second, was estimated using a regression equation that relates the 50-year-flood discharge to drainage area and mean annual precipitation because there are no long-term stream-gaging stations on the river from which to estimate the discharge. The drainage area and mean annual precipitation estimated for Río Catacamas at Catacamas are 45.4 square kilometers and 1,773 millimeters, respectively.

INTRODUCTION

In late October 1998, Hurricane Mitch struck the mainland of Honduras, triggering destructive landslides, flooding, and other associated disasters that overwhelmed the country's resources and ability to quickly rebuild itself. The hurricane produced more than 450 millimeters (mm) of rain in 24 hours in parts of Honduras and caused significant flooding along most rivers in the country. A hurricane of this intensity is a rare event, and Hurricane Mitch is listed as the most deadly hurricane in the Western Hemisphere since the "Great Hurricane" of 1780. However, other destructive hurricanes have hit Honduras in recent history. For example, Hurricane Fifi hit Honduras in September 1974, causing 8,000 deaths (Rappaport and Fernandez-Partagas, 1997).

As part of a relief effort in Central America, the U.S. Agency for International Development (USAID), with help from the U.S. Geological Survey (USGS), developed a program to aid Central America in rebuilding itself. A top priority identified by USAID was the need for reliable flood-hazard maps of Honduras to help plan the rebuilding of housing and infrastructure. The Water Resources Division of the USGS in Washington State, in coordination with the International Water Resources Branch of the USGS, was given the task to develop flood-hazard maps for 15 municipalities in Honduras: Catacamas, Choluteca, Comayagua, El Progreso, Juticalpa, La Ceiba, La Lima, Nacaome, Olanchito, Santa Rosa de Aguán, Siguatepeque, Sonaguera, Tegucigalpa, and Tocoa. This report presents and describes the determination of the area and depth of inundation in the municipality of Catacamas that would be caused by a 50-year flood of Río Catacamas.

The 50-year flood was used as the target flood in this study because discussions with the USAID and the Honduran Public Works and Transportation Ministry indicated that it was the most common design flood used by planners and engineers working in Honduras. The 50-year flood is one that has a 2-percent chance of being equaled or exceeded in any one year and on average would be equalled or exceeded once every 50 years.

Purpose, Scope, and Methods

This report provides (1) results and summary of the hydrologic analysis to estimate the 50-year-flood discharge used as input to the hydraulic model, (2) results of the hydraulic analysis to estimate the water-surface elevations of the 50-year-flood discharge at cross sections along the stream profile, and (3) 50-year-flood inundation maps for Río Catacamas at Catacamas showing area and depth of inundation.

The analytical methods used to estimate the 50-year-flood discharge, to calculate the water-surface elevations, and to create the flood-inundation maps are described in a companion report by Mastin (2002). Water-surface elevations along Río Catacamas were calculated using HEC-RAS, a one-dimensional,

steady-flow, step-backwater computer model; and maps of the area and depths of inundation were generated from the water-surface elevations and topographic information.

The channel and floodplain cross sections used in HEC-RAS were developed from an airborne light-detection-and-ranging (LIDAR) topographic survey of Catacamas and ground surveys at two bridges. Because of the high cost of obtaining the LIDAR elevation data, the extent of mapping was limited to areas of high population density where flooding is expected to cause the worst damage. The findings in this report are based on the conditions of the river channel and floodplains on March 7, 2000, when the LIDAR data were collected, and January 17–18, 2001, when the bridges were surveyed.

Acknowledgments

We acknowledge USAID for funding this project; Jeff Phillips of the USGS for providing data and field support while we were in-country; Roger Bendeck, a Honduran interpreter, for being an indispensable guide, translator, and instrument man during our field trips; and representatives of the mayor's office, who gave us important local insights into the hydrology of and historical flooding along Río Catacamas and allowed us access to the river during our field surveys.

DESCRIPTION OF STUDY AREA

Río Catacamas, which originates in the Montaña de Babilonia mountain range northwest of Catacamas, flows in a southwesterly direction near the western boundary of Catacamas and has a steep gradient throughout the study area reach. The study area includes the channel and floodplains of Río Catacamas from approximately 1.5 kilometers (km) upstream to approximately 3.0 km downstream from Catacamas ([figure 1](#)).

The streambed material of Río Catacamas consists primarily of sand, gravel, and cobbles. The main channel banks and floodplains are generally covered with medium to dense vegetation.

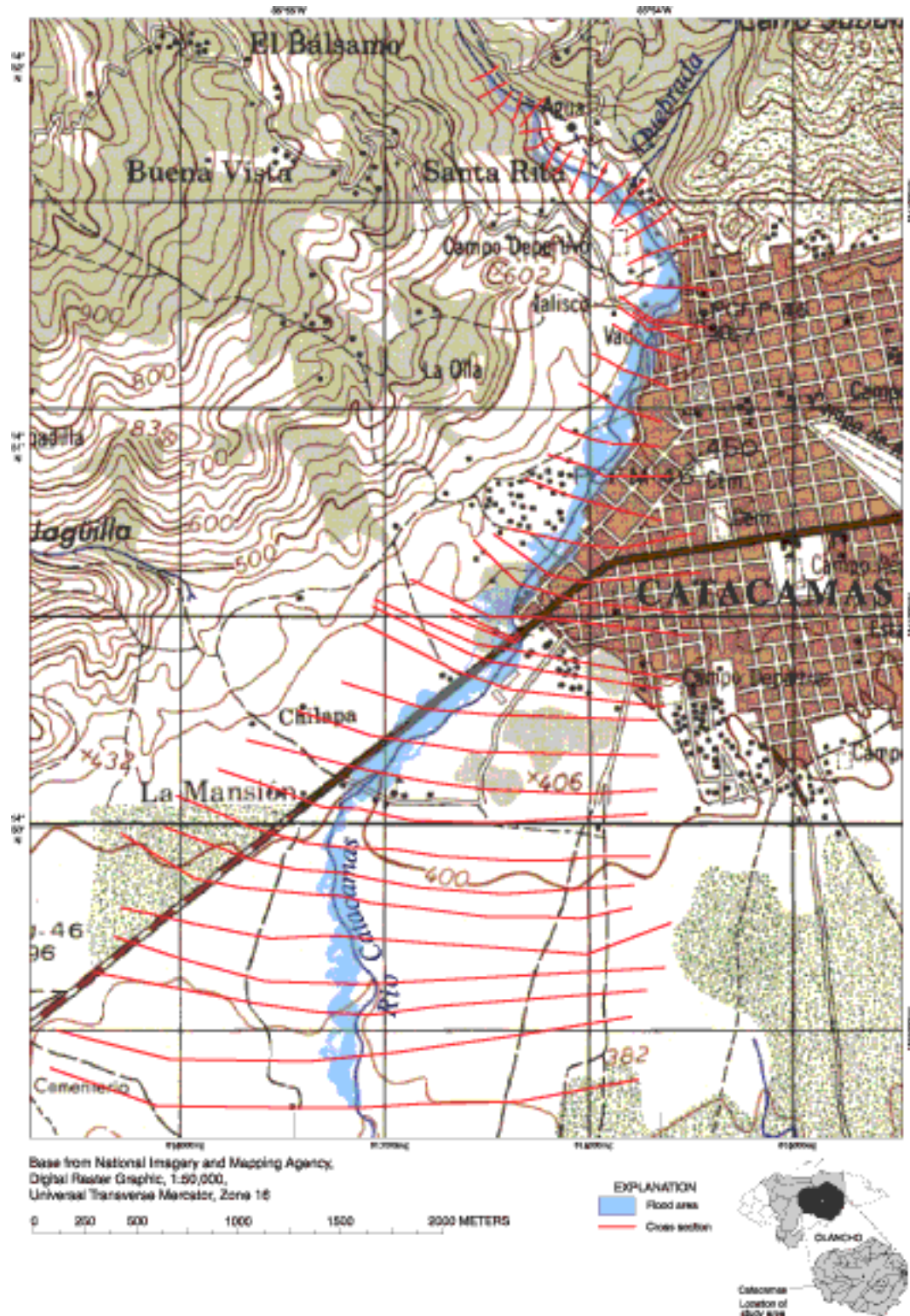


Figure 1. Location of study area and cross sections, and the area of inundation for the 50-year flood on Río Catacamas at Catacamas, Honduras.

FIFTY-YEAR FLOOD DISCHARGE

There are no long-term streamflow records for Río Catacamas. Therefore, the 50-year-flood discharge was estimated using the following regression equation, which was developed using data from 34 streamflow stations throughout Honduras with more than 10 years of annual peak flow record, that relates the 50-year peak flow with drainage basin area and mean annual precipitation (Mastin, 2002).

$$Q_{50} = 0.0788(DA)^{0.5664}(P)^{0.7693}, \quad (1)$$

where

Q_{50} is the 50-year-flood discharge, in cubic meters per second (m^3/s),

DA is drainage area, in square kilometers (km^2), and

P is mean annual precipitation over the basin, in mm.

The standard error of estimate of equation 1, which is a measure of the scatter of data about the regression equation, is 0.260 log unit, or 65.6 percent. The standard error of prediction, which is a measure of how well the regression equation predicts the 50-year-flood discharge and includes the scatter of the data about the equation plus the error in the regression equation, equals 0.278 log unit, or 71.3 percent.

The drainage area of Río Catacamas at Catacamas was calculated to be 45.4 square kilometers (km^2) using a geographic information system (GIS) program to analyze a digital elevation model (DEM) with a 93-meter cell resolution from the U.S. National Imagery and Mapping Agency (Dave Stewart, USGS, written commun., 1999). The mean annual precipitation over the Río Catacamas drainage basin was calculated to be 1,773 millimeters using a GIS program to analyze a digitized map of mean annual precipitation at a scale of 1:2,500,000 (Morales-Canales, 1997–1998, p. 15).

The 50-year-flood discharge estimated from equation 1 for Río Catacamas at Catacamas is 216 cubic meters per second.

WATER-SURFACE PROFILE OF THE 50-YEAR FLOOD

Once a 50-year flood discharge has been estimated, a profile of water-surface elevations along the course of the river can be estimated for the 50-year flood with a step-backwater model, and later used to

generate the flood-inundation maps. The U.S. Army Corps of Engineers HEC-RAS modeling system was used for step-backwater modeling. HEC-RAS is a one-dimensional, steady-flow model for computing water-surface profiles in open channels, through bridge openings, and over roads. The basic required inputs to the model are stream discharge, cross sections (geometry) of the river channels and floodplains perpendicular to the direction of flow, bridge geometry, Manning's roughness coefficients (n values) for each cross section, and boundary conditions (U.S. Army Corps of Engineers, 1998).

Cross-section geometry was obtained from a high-resolution DEM created from an airborne LIDAR survey. The LIDAR survey was conducted by personnel from the University of Texas. A fixed-wing aircraft with the LIDAR instrumentation and a precise global positioning system (GPS) flew over the study area on March 7, 2000. The relative accuracy of the LIDAR data was determined by comparing LIDAR elevations with GPS ground-surveyed elevations at 21 points in the Catacamas study area. The mean difference between the two sets of elevations is -0.356 meter, and the standard deviation of the differences is 0.110 meter. The LIDAR data were filtered to remove vegetation while retaining the buildings to create a "bare earth" elevation representation of the floodplain. The LIDAR data were processed into a GIS (Arc/Info™) GRID raster coverage of elevations at a 1.5-meter cell resolution. The coverage was then processed into a triangular irregular network (TIN) GIS coverage. Cross sections of elevation data oriented across the floodplain perpendicular to the expected flow direction of the 50-year-flood discharge ([figure 1](#)) were obtained from the TIN using HEC-GeoRAS, a pre- and post-processing GIS program designed for HEC-RAS (U.S. Army Corps of Engineers, 2000). The underwater portions of the cross sections cannot be seen by the LIDAR system. However, because the LIDAR surveys were conducted during a period of extremely low flows, the underwater portions were assumed to be insignificant in comparison with the cross-sectional areas of flow during a 50-year flood; therefore, they were not included in the model.

A reconnaissance visit of the study area on October 19, 1999, indicated that there were two bridges over Río Catacamas that needed to be surveyed for inclusion in the HEC-RAS model. One of the bridges is at the main highway crossing of Río Catacamas near the southwest outskirts of Catacamas at station 2.874 and the other is at a small low-water crossing (vado) near the northwest boundary of Catacamas at station 4.737. The geometry of both bridges was surveyed during a field visit on January 17–18, 2001. The vado consists of a low concrete roadbed above culvert-like openings. It is believed that the relatively small culvert-like openings would most likely become plugged with debris during a 50-year flood. Therefore, rather than treat the vado as a bridge section in the HEC-RAS model, the survey of the bridge deck was used to construct a regular channel cross section to represent the vado in the model.

Most hydraulic calculations of flow in channels and overbank areas require an estimate of flow resistance, which is generally expressed as Manning's roughness coefficient, n . The effect that roughness coefficients have on water-surface profiles is that as the n value is increased, the resistance to flow increases also, which results in higher water-surface elevations. The slope of the main channel of Río Catacamas is very steep throughout the study area reach, ranging from about 1 meter per 100 meters at the downstream end of the reach to over 3 meters per 100 meters at the upstream end of the reach. Therefore, Manning's n values for the main channel of Río Catacamas were calculated using an equation for estimating roughness coefficients for steep streams (Jarrett, 1985, p.35). The n values estimated for the main channel ranged from 0.045 to 0.089.

Roughness coefficients for the Río Catacamas floodplains were estimated from digital photographs taken during field visits on October 19, 1999, and January 17–18, 2001, and from computer displays of shaded-relief images of the LIDAR-derived DEM before the vegetation removal filter was applied. The n values estimated for the floodplain areas ranged from 0.050 to 0.080.

Step-backwater computations require a water-surface elevation as a boundary condition at either the downstream end of the stream reach for flows in the subcritical flow regime or at the upstream end of the reach for flows in the supercritical flow regime. Initial HEC-RAS simulations indicated that the flow in most reaches of the Río Catacamas study area would be in the subcritical flow regime, but that supercritical flow would probably occur in some reaches. Therefore, the mixed-flow option of the HEC-RAS model was used because it is able to calculate water-surface elevations for flows in both the subcritical and supercritical flow regimes. Consequently, boundary conditions were determined for both the upstream and downstream ends of the Río Catacamas study reach. A water-surface elevation of 505.95 meters at cross section 6.511, the farthest upstream cross section in the Río Catacamas step-backwater model, was estimated by slope-conveyance computation assuming an energy gradient of 0.0325. A water-surface elevation of 383.22 meters at cross section 0.011, the farthest downstream cross section, was estimated by slope-conveyance computation assuming an energy gradient of 0.0131. The energy gradients at the upstream and downstream ends of the study reach were estimated to be equal to the slope of the main channel bed.

The computed water-surface elevations at the first few cross sections upstream from the downstream end of the study area reach and at the first few cross sections downstream from the upstream end of the reach may differ from the true elevations if the estimated boundary condition elevations are incorrect. However, if the error in the estimated boundary conditions is not large, the computed profile asymptotically approaches the true profile within a few cross sections.

The step-backwater model provided estimates of water-surface elevations at all cross sections for the 50-year-flood discharge on Río Catacamas ([table 1](#) and [figure 2](#)). The water-surface elevation at cross section 2.876, just upstream of the main highway bridge crossing, is nearly as high as the low chord elevation of the bridge. Consequently, even a minor increase in the flood elevation at the bridge could easily cause floodwaters to hit and overtop the bridge, which could result in the failure of the bridge.

Table 1. Estimated water-surface elevations for the 50-year flood on Río Catacamas at Catacamas, Honduras

[Peak flow for the 50-year flood is 216 cubic meters per second. **Cross-section stationing:** distance upstream from an arbitrary point near the model boundary; **Minimum channel elevation, Water-surface elevation:** elevations are referenced to the World Geodetic System Datum of 1984; **Abbreviations:** km, kilometers; m, meters; m/s, meters per second]

Cross-section stationing (km)	Minimum channel elevation (m)	Average velocity of flow (m/s)	Water-surface elevation (m)	Cross-section stationing (km)	Minimum channel elevation (m)	Average velocity of flow (m/s)	Water-surface elevation (m)
6.511	503.17	3.59	505.95	3.926	437.68	2.05	439.08
6.427	500.41	3.67	503.59	3.770	434.87	1.82	436.84
6.347	497.84	4.69	500.60	3.542	430.95	3.96	432.82
6.266	494.68	3.45	498.33	3.288	427.52	1.77	429.18
6.182	492.42	4.89	495.70	3.181	425.55	3.16	427.12
6.085	489.91	4.05	493.28	2.981	423.03	2.18	425.05
5.997	487.68	4.50	490.28	2.876	419.91	3.84	423.77
5.854	482.54	3.39	485.06	2.874 (bridge)			
5.786	480.48	3.79	482.83	2.861	419.91	5.52	422.73
5.696	478.18	3.81	480.67	2.812	420.67	2.33	421.94
5.596	475.42	3.72	477.92	2.719	418.37	1.76	420.25
5.508	473.57	2.20	475.46	2.592	416.57	2.01	418.05
5.425	471.34	2.27	473.30	2.340	412.11	2.04	414.42
5.329	468.96	2.82	470.44	2.091	408.95	2.93	410.67
5.247	466.84	2.18	468.22	1.896	406.49	2.00	408.34
5.117	463.16	2.50	464.63	1.639	402.30	3.82	405.07
4.931	458.46	1.69	460.22	1.433	399.71	2.66	401.54
4.750	454.29	2.17	455.68	1.212	396.50	2.44	399.28
4.724	453.08	1.76	454.99	1.093	394.85	3.33	397.11
4.697	452.80	1.98	454.37	0.873	392.76	1.90	394.89
4.612	450.72	2.34	452.25	0.632	389.20	4.16	391.70
4.465	447.81	1.87	449.41	0.484	387.42	2.20	389.03
4.282	444.51	2.51	446.00	0.270	384.43	2.85	386.47
4.111	440.00	1.42	442.68	0.011	381.21	2.51	383.22

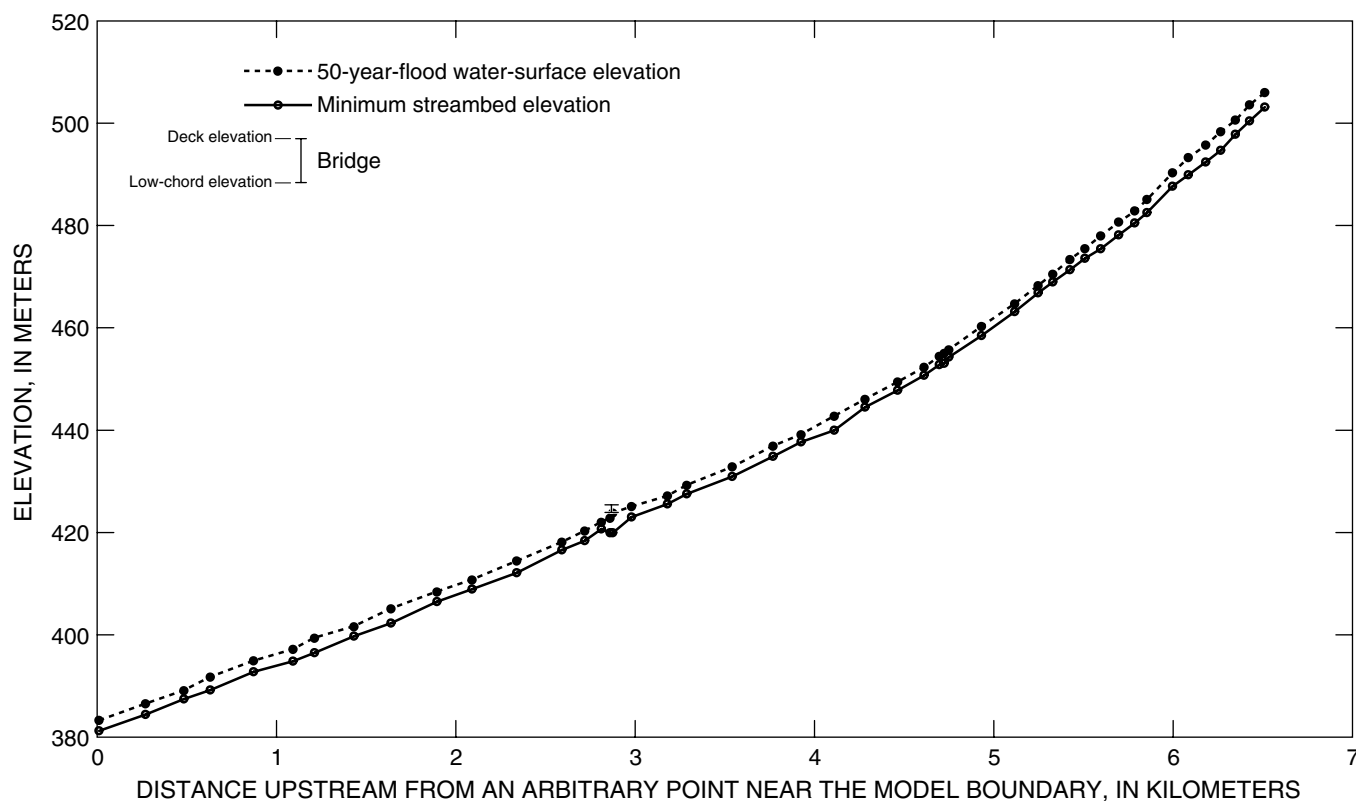


Figure 2. Water-surface profile, estimated using the step-backwater model HEC-RAS, for the 50-year flood on Río Catacamas at Catacamas, Honduras.

FIFTY-YEAR FLOOD-INUNDATION MAPS

The results from the step-backwater hydraulic model were processed by the computer program HEC-GeoRAS to create GIS coverages of the area and depth of inundation for the study area. The GIS coverage of area of inundation was created by intersecting the computed water-surface elevations with the topographic TIN that was produced from the LIDAR data. This coverage was then overlain on an existing 1:50,000 topographic digital raster graphics map ([figure 1](#)) produced by the National Imagery and Mapping Agency (Gary Fairgrieve, USGS, written commun., 1999). Depth of inundation at Catacamas for a 50-year-flood on Río Catacamas ([figure 3](#)) was computed by subtracting the topographic TIN from a computed water-surface elevation TIN to produce a grid with a cell size of 2 meters.

The blue lines depicting the centerline of the Río Catacamas channel on the digital raster graphics map used as the base map for [figure 1](#) lies outside the 50-year-flood boundaries at some locations. This probably results from changes in the river course as a result of flood flows that occurred after the base map was created, especially those that resulted from Hurricane Mitch.

The flood-hazard maps are intended to provide a basic tool for planning or for engineering projects in or near the Río Catacamas floodplain. This tool can reasonably separate high-hazard from low-hazard areas in the floodplain to minimize future flood losses. However, significant introduced or natural changes in main-channel or floodplain geometry or location can affect the area and depth of inundation. Also, encroachment into the floodplain with structures or fill will reduce the flood-carrying capacity and thereby increase the potential height of floodwaters, and may also increase the area of inundation.

DATA AVAILABILITY

GIS coverages of flood inundation and flood depths shown on the maps in [figures 1](#) and [3](#) are available in the Municipal GIS project, a concurrent USAID-sponsored USGS project that will integrate maps, orthorectified aerial photography, and other available natural resource data for a particular municipality into a common geographic database. The GIS project, which is located on a computer in the Catacamas municipality office, allows users to view the GIS coverages in much more detail than shown on [figures 1](#) and [3](#). The GIS project will also allow users to overlay other GIS coverages over the inundation and flood-depth boundaries to further facilitate planning and engineering. Additional information about the Municipal GIS project is available on the Internet at the GIS Products Web page (<http://mitchnts1.cr.usgs.gov/projects/gis.html>), a part of the USGS Hurricane Mitch Program Web site.

The GIS coverages and the HEC-RAS model files for this study are available on the Internet at the Flood Hazard Mapping Web page (<http://mitchnts1.cr.usgs.gov/projects/floodhazard.html>), which is also a part of the USGS Hurricane Mitch Program Web site.

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